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EXPERIMENTAL CHARACTERIZATION OF THE THRUST INDUCED BY LASER ABLATION ON AN ASTEROID

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ABSTRACT

Previous analysis gained from a series of experiments has demonstrated the effectiveness of laser ablation at providing contactless deflection of Near Earth Asteroids. This included the operational margins, performance and tolerance of the ablating spacecraft. The contamination caused by the ablated ejecta plume was shown to be significantly less than theoretically predicted. There was a reduction in the growth, density and absorptivity of the deposited ejecta. The deposited ejecta was also loosely bounded to the underlying substrate. It could therefore be easily removed and mitigated by applying a small vibration and/or increase in the local surface temperature. These factors increased the achievable, ablation-induced deflection distance, where there was no immediate saturation of any exposed surface. From these initial investigations, a set of more detailed and comprehensive laser ablation experiments have been performed. This aimed to improve the current mass flow rate and thrust models.

The mathematical model describing laser ablation is currently based on three fundamental assumptions: 1) the formation of the ejecta plume is similar to the rocket exhaust in standard methods of rocket propulsion; 2) the asteroid is a spherical, dense and homogenous body and 3) the ablated particles of ejecta will immediately re-condense and stick to any exposed surface.

The first experiment campaign was performed with a 90 watt, continuous wave, fibre laser. Under vacuum it has demonstrated that the contamination of the exposed surface was less than predicted by the numerical model. However, at the same time, the test campaign revealed some interesting discrepancies. This existed between the measured and theoretically predicted mass flow rate of the ablated material

To address these discrepancies, more detailed experiments have been performed. This has been achieved by in-situ measurements of the ablated mass flow rate, the temperature development of the ejecta plume and orientation of the thrust direction. It has enabled specific advancements within the ablation model to be considered. This includes the latent heat of complete sublimation, energy absorption within the target material and in the formation of the Knudsen layer, and the incongruent ablation of the target material. It is of paramount importance to understand the three dimensional energy balance of sublimation and the effects of a de-focused laser beam.

Different experiments were conducted to examine the ablation response of a range of a number of different asteroid analogue target materials. This aimed to represent the diversity within the Near Earth asteroid population. It is inclusive of re-accumulated rubble piles, monolithic structures and porous bodies.

This paper therefore reports on the new results and analysis gained from the laser ablation experiments. It will present, in detail, the recently advanced ablation model and its overall effect on the mission analysis and design of any laser ablation based deflection mission. Furthermore, the paper will show whether the momentum coupling achieved through laser ablation is better than that of an ion-engine based system.

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